COMBINING SEISMIC AND GEOTECHNICAL METHODS TO IMPROVE THE PREDICTION OF PHYSICAL SOIL PROPERTIES

BADEE ALSHAMERI

A thesis submitted in
fulfilment of the requirement for the award of the
Doctor of Philosophy

Faculty of Civil and Environmental Engineering
Universiti Tun Hussein Onn Malaysia

JUNE 2017

For my beloved wife Nawal, my sons Elyas and Muhammad, my mother and father, my sisters and brother, and my sister in law

ACKNOWLEDGEMENT

I would like to express my sincere appreciation to my supervisor, Professor Emeritus Dato' Dr. Ismail Bakar, co-supervisor Associate Professor Dr. Aziman Madun, Ministry of High Education Yemen, and Ministry of Higher Education of Malaysia for the support that given throughout the duration of my Ph.D. study

ABSTRACT

Seismic investigation offers subsurface information in a cost and time effective way compared with the geotechnical methods. The seismic data (i.e. bender element data) needs to be correlated with geotechnical data allowing it to be adopted in engineering designs. However, the procedures and analysis of bender element (BE) data can be subjected to crucial errors due to several limitations in the BE tools such as the magnitude of seismic source and frequency range. In addition, little attention had been paid to adopt field BE despite the other field seismic methods having low resolution when assessing the properties of the thin targeting layers of soil as pavement layers. Therefore, this research aim was to evaluate the limitations and reliability of BE procedure in the laboratory and the field. The research had two main stages; laboratory and model stages. In the laboratory stage, the BE limitations were assessed using homogeneous and unchanged properties of polystyrene sample instead of soil. In addition, various mixtures of sand-kaolin were investigated using the shear box, compaction and BE to obtain its empirical correlation as well as the obtained result was used to construct the soil model. In the model stage, the multi-thin layers model consisting of sand-kaolin mixtures was constructed for the purpose of suggesting the field BE procedure. The laboratory BE results recommended that the two sensors relative rotation shall be less than 50^{o}, the position of two sensors alignment ratio between the horizontal and vertical distance shall be less than 0.5, and the effect of sample boundary occured when the ratio between the distance to sample boundary and the sample thickness less than 0.38. In model stage; the recommended procedure to be adopted in the field was via placing the BE sensors spacing less than 1 m and the BE crosshole method via placing the sensors at both side of the targeted layer was the best option. However, this method required some of the testing preparation. In conclusion, the BE limitations and procedures in the laboratory and field had been evaluated and investigated then recommended the procedures to improve the reliability of the BE results.

ABSTRAK

Penyiasatan seismik dapat memberikan maklumat subpermukaan dengan kos dan masa yang efektif berbanding menggunakan kaedah geoteknikal yang konvensional. Data seismik diperolehi dengan kaedah unsur bender perlu dikaitkan dengan data geoteknik bagi membolehkan data ini diguna pakai dalam reka bentuk kejuruteraan. Walaubagaimanapun, prosedur dan analisa data unsur bender (BE) terdedah kepada kesalahan disebabkan oleh beberapa limitasi peralatan BE seperti magnitud sumber seismik dan julat frequensi. Tambahan pula hanya sedikit sahaja perhatian yang diberikan berkaitan denganpenggunaan BE di lapangan walaupun telah diketahui bahawa kaedah seismik konvensional menghadapi masalah resolusi yang rendah bagi menilai lapisan tanah yang nipis seperti lapisan turapan. Oleh yang demikian, matlamat kajian ini adalah untuk menilai limitasi dan kebolehpercayaan kaedah BE di makmal dan di lapangan. Kajian dibahagi kepada dua peringkat utama iaitu di makmal dan model. Di peringkat makmal, limitasi BE dinilai dengan menggunakan polystyrene yang homogen dan tidak berubah sifat berbanding dengan menggunakan tanah. Di samping itu, pelbagai campuran antara pasir dan kaolin dikaji menggunakan ujian ricih, pemadatan dan BE bagi mendapatkan korelasi empirikal dan menggunakan keputusan tersebut bagi membina model untuk kajian seterusnya. Di peingkat model, pelbagai lapisan tanah nipis yang terdiri dari campuran pasir dan kaolin dibina bagi tujuan mendapatkan prosedur BE di lapangan. Di makmal, keputusan BE mencadangkan kedudukan putaran relatif dua sensor mestilah kurang 50°, dan kedudukan nisbah jajaran dua sensor antara jarak mendatar dan menegak mestilah kurang 0.5, dan kesan sempadan sampel terjadi apabila nisbah jarak antara sempadan sampel dan ketebalan sampel kurang dari 0.38. Pada peringkat model, mencadanganankan prosedur di lapangan adalah dengan meletakkan jarak sensor BE kurang dari 1 m dan menggunakan kaedah lubang silang BE dengan meletakkan sensor di kedua hujung lapisan yang dikaji. Walaubagaimanapun kaedah ini memerlukan persiapan lapangan yang lebih. Kesimpulannya, limitasi dan kaedah BE di makmal dan lapangan telah berjaya dinilai, dikaji dan prosedur untuk membaiki kebolehpercayaan keputusan BE telah dicadangkan.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ΔF	-	Applying shear force (i.e. tangential force)
Δh	-	Changing in rod high (i.e. length)
Δl	-	Displacement
ΔLr	-	Changing in the rod length
ΔW	-	Amount of decrease the width
A	-	Cross sectional area
a	-	Soil constant
ACR	-	Amplitude comparison ratio
A_r	-	Amplitude of receiver in millivolt
A_s	-	Amplitude of transmitter in volte
BE	-	Bender element
BEAT	-	Bender element analysis tools
BHS	-	Seismic borehole
c	-	Cohesion
CC_{excel}	-	Cross-correlation using excel
CC_{GDS}	-	Cross-correlation methods using beat
$CC\text{-}norm_{excel}$	-	Normalized correlation coefficient
CC_{xy} (t_s)	-	Time for maximum value of cross-correlation
CH	-	Crosshole method
CHm	-	Multi-layer crosshole
CHS	-	Seismic crosshole method
CL	-	Clay content
CPT	-	Cone penetration test
CPTu	-	Piezocone penetration tests
CSW	-	Continuous surface wave

D	-	Sample thickness
d_1	-	Distance between R_1 and R_2
d_2	-	Distance between S and R
d_{50}	-	Mean particle size at 50% of percent finer
DC	-	Dynamic compaction
Dh	-	Horizontal distance to centre axis of the sample
DH	-	Downhole method
DHS	-	Seismic downhole method
d_i	-	Shear box diameter
d_{max}	-	Maximum particle size
Dr	-	Distance to the boundary
E	-	Young's modulus
e	-	Void ratio
e_0	-	In-situ void ratio
E_0	-	Initial Young's modulus
e_{gk}	-	Gravel skeleton void ratio
E_{max}	-	Maximum Young's modulus
e_s	-	Intergranular void ratio
e_{sk}	-	Sand skeleton void ratio
f	-	Frequency *f*
F	-	Applied force F
fc	-	Compressive strength
FC	-	Fine content FC
G	-	Shear modulus (i.e. modulus of the shear rigidity)
G_0	-	Initial shear modulus
GC	-	Gravel content
GDS	-	Global digital systems
G_{max}	-	Maximum shear modulus
G_s	-	Specific gravity
G_{sf}	-	Specific gravity for fine material
h	-	Height (i.e. Length) of the rod
H_s	-	Sample high in direct shear test
l	-	Length of cube of material

L	-	Wave path length
l_b	-	Intruded length of the sensor
Lr	-	Original length of rod
L_{tt}	-	Wave path length from tip of transmitter to tip of receiver
M_1	-	Mass of moist container
M_2	-	Mass of dry container and soil
MASW	-	Multi-channel analyses of surface waves
MDD	-	Maximum dry density
M_{equal}	-	Mass of equal water
M_{md}	-	Mass of dry compaction mould
M_{p1}	-	Mass of dry pycnometer
M_{p2}	-	Mass of dry pycnometer and mixture
M_{p3}	-	Mass of saturated pycnometer and mixture
M_{p4}	-	Mass of pycnometer and water
M_s	-	Mass of the solid
MSW	-	Municipal solid waste
M_t	-	Mass of moist soil in mould
$\mathrm{M_t}$	-	Mass of compacted sample and mould
M_w	-	Mass of water
M_w	-	Mass of solid material
N	-	Uncorrected blow account for SPT
n	-	Elastic constant
OMC	-	Optimum moisture content
P	-	Original confining pressure
P_a	-	Atmospheric pressure
P-wave	-	Primary (compression) wave
q_a	-	Allowable bearing capacity
q_c	-	Cone tip resistance
q_f	-	Ultimate bearing capacity
q_t	-	Corrected cone tip resistance
R_1, R_2	-	Sensor number 1 and sensor number 2
RC	-	Resonant column
ReMi	-	Refraction microtremor

RS	-	Receiver signal
SASW	-	Spectral analysis of surface waves
SC	-	Sand content
SCPT	-	Seismic cone penetrometer test
SPT	-	Standard penetration test
SR	-	Seismic refraction
SS	-	Seismic suspension
S-wave	-	Secondary (shear) wave
t	-	Travel time
T	-	Corresponding to the signal time record
t_{100}	-	Time at the peak shear stress
t_{50}	-	Time at 50 % of the peak shear stress
ts	-	Time shift for transmitter signal
V_1	-	Velocity at first layer
V_2	-	Velocity at second layer
V_c	-	Volume of coarse content
V_E	-	Extensional wave velocity in narrow bar (equal to V_p)
V_f	-	Volume of fine content
V_m	-	Volume of the mould
V_P	-	Compression wave velocity
$V_{P, C\text{-}C}$	-	Compression wave from first-deflection methods (C-C)
$V_{P, D\text{-}D}$	-	Compression wave from first-peak methods (D-D)
$V_{P, F\text{-}F}$	-	Compression wave from first-trough methods (F-F)
V_{P2}	-	Compression wave velocity from the second wave cycle
$V_{P2, C\text{-}C*}$	-	Compression wave from second deflection methods (C-C*)
$V_{P2, D\text{-}D*}$	-	Compression wave from second pick methods (D-D*)
$V_{P2, F\text{-}F*}$	-	Compression wave from second trough methods (F-F*)
V_{PR}	-	Reflected P-wave
V_R	-	Rayleigh wave velocity
V_S	-	Shear wave velocity
$V_{S, C\text{-}A, near\text{-}field}$	-	Shear wave from first-deflection methods inside the near-field zone (C-C)
$V_{S, C\text{-}C}$	-	Shear wave from first-deflection methods (C-C)

$V_{S,\ D\text{-}D}$	-	Shear wave from first-peak methods (D-D)
$V_{S,\ F\text{-}F}$	-	Shear wave from first-trough methods (F-F)
V_{S2}	-	Shear wave velocity from the second wave cycle
$V_{S2,\ C\text{-}C^*}$	-	Shear wave from second deflection methods (C-C*)
$V_{S2,\ D\text{-}D^*}$	-	Shear wave from second pick methods (D-D*)
$V_{S2,\ F\text{-}F^*}$	-	Shear wave from second trough methods (F-F*)
V_v	-	Volume of voids
W	-	Original width of rod
w	-	Moisture content
w_{sat}	-	Saturation point
X(T)	-	Corresponds to receiver signal
Xc	-	Critical distance
Xcr	-	Crossover distance
Y(T)	-	Corresponding to transmitter signal
z	-	Depth
γ	-	Unit weight
γ_d	-	Dry unit weight
γ_{MDD}	-	Unit weight of maximum dry density
γ_t	-	Total unit weight
γ_w	-	Unit weight of water
ε	-	Strain
ε_{100}	-	Shear strain at the peak shear stress
ε_{50}	-	Shear strain at 50 % of the peak shear stress
θ_c	-	Critical angle
θi	-	Incidence angle
θ_r	-	Refracted angle
λ	-	Wavelength
μ	-	Shear modulus (same as G)
ν	-	Poisson’s ratio
ρ	-	Bulk density
ρ_d	-	Dry density
ρ_m	-	Moist density
ρ_{wet}	-	Wet density

σ	-	Applied normal stress (i.e. confining stress)
σ_v	-	Overburden pressure
σ'_v	-	Effective vertical stress
τ	-	Shear strength
ϕ	-	Friction angle
ϕ'	-	Effective friction angle

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Both geotechnics and seismic methods have numerous approaches to measure soil properties. These methods are classified as field or laboratory tests (Das & Sobhan, 2014; Reynolds, 2011). Geotechnical testing (e.g. shear box, triaxial test, and unconfined compression test) provides strength parameters which is used directly in the engineering design. While seismic methods assess geomaterial characterisations (e.g. seismic wave velocity) which is used to predict the design's parameters (e.g. strength parameters) using empirical correlation equations (Milsom & Eriksen, 2011; Mayne *et al.*, 2002).

The seismic methods need to be improved to overcome difficulties related to the data quality. The seismic data is less effective in engineering design compared with geotechnical data (i.e. direct data) where the design parameters are predicted rather than measured directly (Martínez *et al.*, 2015; Foti *et al.*, 2014). Seismic data can be improved by combining the different seismic methods to avoid the weakness of predicted data and correlating the seismic data to the geotechnical data. The advantages of seismic investigation compared with the geotechnical methods include; (a) cost and time efficiency, (b) being a non-destructive test and non-invasive method, and (c) suitable for investigating areas where it is difficult to use the direct methods due to high cost or contamination, etc. (Shokri *et al.*, 2016; Martinho & Dionísio, 2014).

Seismic methods had seen rapid development in recent decades, and the range of their usage has broadened. For example, seismic reflection and refraction methods are being used in deep exploration while the surface wave methods are used in the shallow investigation. Both seismic reflection and refraction depend on analysing the body waves while the surface wave methods depend on analysis the surface waves. The seismic refraction, reflection and surface wave analysis methods are classified as field methods. While the bender element (BE) and the ultrasonic methods are used in the laboratory to measure the body seismic wave velocities V_P and V_S (i.e. primary and shear seismic wave velocities respectively).

The bender element BE has been commonly used in the laboratory due to its simplicity, versatility, relative small sensors, the flexibility of using sensors in a different direction, fast, inexpensive, and non-destructive method (Valle-Molina & Stokoe, 2012). Despite its many advantages, several factors can nevertheless affect the BE data leading to pseudo results. These factors include; (a) length of sensors, (b) sensor alignment, (c) sensor rotation, (d) boundary condition, (e) near-field effect, (f) signal noise, and (g) signal damping (Moldovan *et al.*, 2016; Karray *et al.*, 2015). Although some of these parameters had been studied by previous researchers, their direct application had not been examined. For example, Zeng *et al.* (2007), Lee & Santamarina (2005), and Clayton *et al.* (2004) mentioned the effect of the sensor alignments and sensor rotation, but they did not provide a clear definition of the effective zones of these parameters. The near-field effect had been studied, but the results had recommended different ratios of wave path length to the wavelength (L_{tt}/λ) which questions the efficiency of the recommended ratios (Leong *et al.*, 2009; Jovicic *et al.*, 1996; Viggiani & Atkinson 1995a; Sa´nchez-Salinero *et al.*, 1986).

Although the bender element is used commonly in the laboratory, little attention had been paid to developing the usage of the bender element in the field. The field BE method can be useful for examining thin soil layers (e.g. compaction layers and pavement) where the resolution of other seismic methods was low and subjected to several limitations rendering its results uncertain (Castellaro *et al.*, 2015; Everett, 2013). Most BE field trials were applied in a single layer while field conditions are often multi-layer. Moreover, there is no specific definition for the boundary condition

REFERENCES

Agan, C. & Algin, H. M. (2014). Determination of Relationships Between Menard Pressuremeter Test and Standard Penetration Test Data using ANN model: a Case Study on the Clayey Soil in Sivas, Turkey. *Geotechnical Testing Journal*, 37(3): 1-12. DOI:10.1520/GTJ20130123

Alramahi, B. (2007). *Characterization of Unsaturated Soils Using Elastic and Electromagnetic Waves*. Louisiana State University. Ph.D. thesis.

Alshameri, B. (2011). *Engineering Properties of Older Alluvial*. Universiti Teknologi Malaysia. Malaysia. Master Thesis.

Alvarado, G. & Coop, M. R. (2012). On the performance of bender elements in triaxial tests. *Géotechnique*, 62(1): 1-17. DOI 10.1680/geot.7.00086.

Amat, A. S. (2007). Elastic Stiffness Moduli of Hostun Sand. Project Report. Department of Civil Engineering, University of Bristol, UK.

American Society for Testing and Materials (2005). *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*. ASTM International, West Conshohocken, PA, USA. D2216.

American Society for Testing and Materials (2006). *Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation*. United States. D5777.

American Society for Testing and Materials (2007). *Standard Test Method for Particle Size Analysis of Soil*s. ASTM International, West Conshohocken, PA, USA. D422.

American Society for Testing and Materials (2007). *Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Cohesive Soils*. ASTM International, West Conshohocken, PA, USA. D6528.

American Society for Testing and Materials (2008). *Standard Test Method for Laboratory Determination of Pulse Velocities and Ultrasonic Elastic Constants of Rock*. ASTM International, West Conshohocken, Pennsylvania. D2845.

American Society for Testing and Materials (2010). *Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer*. ASTM International, West Conshohocken, PA, USA. D854.

American Society for Testing and Materials (2011). *Standard Test Methods for Direct Shear Test of Soils Under Consolidated Drained Conditions*. ASTM International, West Conshohocken, PA, USA. D3080.

American Society for Testing and Materials (2012). *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12400 ft-lbf/ft^3 (600 kN-m/m^3))*. ASTM International, West Conshohocken, PA, USA. D698.

American Society for Testing and Materials (2012). *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))*. ASTM International, West Conshohocken, PA, USA. D1557.

Amšiejus, J., Dirgėlienė, N., Norkus, A. & Skuodis, Š. (2014). Comparison of sandy soil shear strength parameters obtained by various construction direct shear apparatuses. *Archives of civil and mechanical engineering*, 14(2): 327-334. DOI: 10.1016/j.acme.2013.11.004.

Anderson, N. Ismail, A. & Davisc, C. (2006a). Selection of Appropriate Geophysical Techniques: A Generalized Protocol Based on Engineering Objectives and Site Characteristics. *Proc., 2006 Highway Geophysics- NDE Conference*, 2006, pp. 29–47.

Anderson, N. Thitimakorn, T. Hoffman, D. Stephenson, R. & Luna, R. (2006b). Comparison of Four Geophysical Methods for Determining the Shear Wave Velocity of Soils. *6th International Conference and Exposition on Petroleum Geophysics*. Kolkata. India. 2006. pp. 1002-1007.

Aris, M., Benahmed, N. & Bonelli, S. (2012). Experimental Geomechanics: A Laboratory Study on the Behaviour of Granular Material Using Bender Elements. *European Journal of Environmental and Civil Engineering*, 16(1): 97-110.

Arosio, D., Longoni, L., Papini, M. & Zanzi, L. (2013). Seismic characterization of an abandoned mine site. *Acta Geophysica*, 61(3): 611-623.

Arroyo, M. (2007). Wavelet Analysis of Pulse Tests in Soil Samples. *Ital. Geotech. J*, 30, 26-38.

Arroyo, M., Greening, P. D. & Muir-Wood, D. (2003b). An estimate of uncertainty in current laboratory pulse test practice. *Rivista Italiana di Geotecnica*, 37(1): 17-35.

Arroyo, M., Medina, L. & Muir Wood, D. (2002). Numerical Modelling of Scale Effects in Bender-Based Pulse Tests. NUMOG VIII, Pande, GN and Pietruszczak, S. (eds): 589-594.

Arroyo, M., Muir Wood, D. & Greening, P. D. (2003a). Source near-field effects and pulse tests in soil samples. *Géotechnique*, 53(3): 337-345.

Arroyo, M., Wood, D.M., Greening, P.D., Medina, L. & Rio, J. (2006). Effects of sample size on bender-based axial G_0 measurements. *Géotechnique*, 56(1), pp.39-52. DOI: 10.1680/geot.2006.56.1.39.

Arulnathan, R., Boulanger, R. W. & Riemer, M. F. (1998). Analysis of Bender Element Tests. *Geotechnical Testing Journal, GTJODJ*, 21(2): 120-131.

Arulnathan, R., Boulanger, R. W., Kutter, B. L. & Sluis, W. K. (2000). New Tool for Shear Wave Velocity Measurements in Model Tests. *Geotechnical testing journal*, 23(4): 444-453.

Atkinson, J. (1993). *An Introduction to the Mechanics of Soils and Foundations: Through Critical State Soil Mechanics*. London. McGraw-Hill International Series in Civil Engineering.

Atkinson, J. (2007). *The mechanics of soils and foundations*. 2nd ed. London and New York. CRC Press.

Ayolabi, E. A. & Adegbola, R. B. (2014). Application of MASW in road failure investigation. *Arabian Journal of Geosciences*, 7(10): 4335-4341.

Bai, F. Q. & Liu, S. H. (2012). Measurement of the shear strength of an expansive soil by combining a filter paper method and direct shear tests. *Geotechnical Testing Journal*, 35(3): 451-459. DOI: 10.1520/GTJ103342.

Bartake, P., Patel, A. & Singh, D. (2008). Instrumentation for Bender Element Testing of Soils. *International Journal of Geotechnical Engineering*, 2(4): 395-405. DOI 10.3328/IJGE.2008.02.04.393-404.

Bartake, P.P. & Singh, D.N. (2007). Studies on Determination of Shear Wave Velocity in Sands. *Geomechanics and Geoengineering: An International Journal*, 2(1): 41-49.

Bate, B., Choo, H. & Burns, S. E. (2013). Dynamic properties of fine-grained soils engineered with a controlled organic phase. *Soil Dynamics and Earthquake Engineering*, 53, 176-186. doi: 10.1016/j.soildyn.2013.07.005.

Baziw, E. & Verbeek, G. (2014). Methodology for Processing Seismograms Containing Total Internal Reflections. *Geoscience and Remote Sensing, IEEE Transactions on*, 52(11): 7073-7085.

Baziw, E. J. (1993). Digital filtering techniques for interpreting seismic cone data. *Journal of geotechnical engineering*, 119(6): 998-1018.

Belkhatir, M., Arab, A., Della, N., Missoum, H. & Schanz, T. (2010). Influence of inter-granular void ratio on monotonic and cyclic undrained shear response of sandy soils. *Comptes Rendus Mecanique*, 338(5): 290-303. DOI:10.1016/j.crme.2010.04.002.

Belkhatir, M., Schanz, T., Arab, A. & Della, N. (2014). Experimental Study on the Pore Water Pressure Generation Characteristics of Saturated Silty Sands. *Arabian Journal for Science and Engineering*, 39(8): 6055-6067. DOI 10.1007/s13369-014-1238-9.

Bellotti, R., Jamiolkowski, M., Presti, D. L. & O'neill, D. A. (1996). Anisotropy of Small Strain Stiffness in Ticino Sand. *Geotechnique*, 46(1): 115-131.

Benson, R. C. & Yuhr, L. B. (2015). *Site Characterization in Karst and Pseudokarst Terraines: Practical Strategies and Technology for Practicing Engineers, Hydrologists and Geologists*. New York London Springer.

Bensoula, M., Missoum, H. & Bendani, K. (2015). Critical undrained shear strength of loose-medium sand-silt mixtures under monotonic loadings. *Journal of Theoretical and Applied Mechanics*, 53(2): 331-344. DOI: 10.15632/jtam-pl.53.2.331.

Blewett, J., Blewett, I. J. & Woodward, P. K. (1999). Measurement of Shear-Wave Velocity Using Phase-Sensitive Detection Techniques. *Canadian geotechnical journal*. 36(5): 934–939.

Blewett, J., Blewett, I. J. & Woodward, P. K. (2000). Phase and Amplitude Responses Associated with the Measurement of Shear-Wave Velocity in Sand by Bender

Elements. *Canadian Geotechnical Journal*. 37(6): 1348-1357. DOI 10.1139/t00-047.

Boulanger, R. W., Arulnathan, R., Jr, L. F. H., Torres, R. A. & Driller, M. W. (1998). Dynamic properties of Sherman Island peat. *Journal of Geotechnical and Geoenvironmental Engineering*, 124(1): 12-20.

Brandenberg, S. J., Choi, S., Kutter, B. L., Wilson, D. W. & Santamarina, J. C. (2006). A Bender Element System for Measuring Shear Wave Velocities in Centrifuge Models. In Zhang and Wang (Eds) *Physical Modleing in Geotechnics–6th ICPMG–Ng*. pp. 165-170.

Brignoli, E. G. M., Gotti, M. & Stokoe, K. H. (1996). Measurement of Shear Waves in Laboratory Specimens by Means of Piezoelectric Transducers. *Geotechnical testing journal*, 19(4): 384-397.

Burns, S. E. & Mayne, P. W. (1996). Small-And High-Strain Measurements of In-Situ Soil Properties Using the Seismic Cone Penetrometer. *Transportation Research Record: Journal of the Transportation Research Board*, 1548(1): 81-88.

Camacho-Tauta, J. F. (2011). *Evaluation of the small-strain stiffness of soil by non-conventional dynamic testing methods*. Instituto Superior Técnico, PhD thesis.

Camacho-Tauta, J. F., Álvarez, J. D. J. & Reyes-Ortiz, O. J. (2012). A Procedure to Calibrate and Perform the Bender Element Test. *Dyna*, 79(176): 10-18.

Capizzi, P. & Martorana, R. (2014). Integration of constrained electrical and seismic tomographies to study the landslide affecting the cathedral of Agrigento. *Journal of Geophysics and Engineering*, 11(4): 045009.

Carpenter, P. J., Reddy, K. R. & Thompson, M. D. (2012). Seismic Imaging of a Leachate-Recirculation Landfill: Spatial Changes in Dynamic Properties of Municipal Solid Waste. *Journal of Hazardous, Toxic, and Radioactive Waste,* 17(4): 331-341.

.

Castellaro, S., Panzeri, R., Mesiti, F. & Bertello, L. (2015). A surface seismic approach to liquefaction. *Soil Dynamics and Earthquake Engineering*, 77, 35-46.

Cerato, A. B. & Lutenegger, A. J. (2006). Specimen size and scale effects of direct shear box tests of sands. *Geotechnical Testing Journal*, 29(6): 507.

Cha, M. & Cho, G. (2007). Shear Strength Estimation of Sandy Soils Using Shear Wave Velocity. *Geotechnical Testing Journal*, 30(6). GTJ100011 1-12. doi:10.1520/GTJ100011.

Chanda, M. & Roy, S. K. (2007). *Plastics technology handbook.* 4th ed. London & New York. CRC press.

Chang, I. H., Cho, G. C., Lee, J. G. & Kim, L. H. (2006). Characterization of clay sedimentation using piezoelectric bender elements. *In Key Engineering Materials,* 321, 1415-1420.

Chang, K. T., Kang, Y. M., Ge, L. & Cheng, M. C. (2015). Mechanical Properties of Gravel Deposits Evaluated by Nonconventional Methods. *Journal of Materials in Civil Engineering*, 27(11): 04015032. doi:10.1061/(ASCE)MT.1943-5533.0001287.

Chang, W. J., Chang, C. W. & Zeng, J. K. (2014). Liquefaction characteristics of gap-graded gravelly soils in K 0 condition. *Soil Dynamics and Earthquake Engineering,* 56, 74-85. doi:10.1016/j.soildyn.2013.10.005.

Chapman, C. (2004). *Fundamentals of Seismic Wave Propagatio*n. London & New York. Cambridge University Press.

Chen, X., Zhang, J., Xiao, Y. & Li, J. (2015). Effect of roughness on shear behavior of red clay–concrete interface in large-scale direct shear tests. *Canadian Geotechnical Journal*, 52(8): 1122-1135. DOI: 10.1139/cgj-2014-0399.

Chenari, R. J., Tizpa, P., Rad, M. R. G., Machado, S. L. & Fard, M. K. (2015). The use of index parameters to predict soil geotechnical properties. *Arabian Journal of Geosciences,* 8(7): 4907-4919. DOI 10.1007/s12517-014-1538-0.

Chinkulkijniwat, A., Man-Koksung, E., Uchaipichat, A. & Horpibulsuk, S. (2010). Compaction characteristics of non-gravel and gravelly soils using a small compaction apparatus. *Journal of ASTM International,* 7(7).

Choo, H. & Burns, S. E. (2015). Shear wave velocity of granular mixtures of silica particles as a function of finer fraction, size ratios and void ratios. *Granular Matter,* 17(5): 567-578. DOI: 10.1007/s10035-015-0580-2.

Choo, H., Yeboah, N. N. & Burns, S. E. (2016). Small to intermediate strain properties of fly ashes with various carbon and biomass contents. *Canadian Geotechnical Journal,* 53(1): 35-48. doi:10.1139/cgj-2014-0069.

Choudhury, D. & Savoikar, P. (2009). Simplified method to characterize municipal solid waste properties under seismic conditions. *Waste management,* 29(2): 924-933.

Clariá, J. J. & Rinaldi, V. A. (2007). Shear wave velocity of a compacted clayey silt. *Geotechnical Testing Journal,* 30(5): 1-10. doi:10.1520/GTJ100655.

Clayton, C. R. I., Theron, M. & Best, A. I. (2004). The measurement of vertical shear-wave velocity using side-mounted bender elements in the triaxial apparatus. *Géotechnique,* 54(7): 495-498. DOI 10.1680/geot.2004.54.7.495.

Connolly, T. M. & Kuwano, R. (1999). The measurement of G^ in a resonant column, bender element, torsional shear apparatus, In Jamiolkowski, M. B., Lancellotta, R. & Presti, D. L. (Eds.). (1999). *Pre-Failure Deformation of Geomaterials*: Proceedings International Symposium, Torino, Italy (Vol. 1, p. 73). CRC Press.

Cubrinovski, M. & Rees, S. (2008). Effects of fines on undrained behaviour of sands. *Geotechnical Earthquake Engineering and Soil Dynamics IV*: pp. 1-11. doi: 10.1061/40975(318)91.

Dadkhah, R., Ghafoori, M., Ajalloeian, R. & Lashkaripour, G. R. (2010). The Effect of scale direct shear test on the strength parameters of clayey sand in Isfahan City, Iran. *Journal of Applied Sciences(Faisalabad),* 10(18): 2027-2033.

Das, B. & Sobhan, K. (2014). *Principles of Geotechnical Engineering*. 8th ed. USA. Cengage Learning.

Day, R. W. (2010). *Foundation Engineering Handbook: Design and Construction with the 2009 International Building Code*. 2nd ed. New York. McGraw-Hill.

De Alba, P., Baldwin, K., Janoo, V., Roe, G. U. & Celikkol, B. (1984). Elastic-Wave Velocities and Liquefaction Potential. *Geotechnical Testing Journal*, 7 (2): 77-87.

Duffy, B., Campbell, J., Finnemore, M. & Gomez, C. (2014). Defining fault avoidance zones and associated geotechnical properties using MASW: a case study on the Springfield Fault, New Zealand. *Engineering Geology,* 183, 216-229.

Ekwue, E. I. & Seepersad, D. (2015). Effect of soil type, peat, and compaction effort on soil strength and splash detachment rates. *Biosystems Engineering*, 136, 140-148. DOI: 10.1016/j.biosystemseng.2015.06.004.

El-Hussain, I., Mohamed, A. M. E., Deif, A., Al-Rawas, G., Al-Jabri, K. & Pekman, G. (2014). Delineation of a paleo-channel utilizing integrated geophysical techniques at the port of duqm area, sultanate of oman. *Journal of Geophysics and Engineering,* 11(5): 055005.

El-Sekelly, W., Abdoun, T. & Dobry, R. (2012). Soil characterization in centrifuge models through measurement of shear wave velocities using bender elements. In *GeoCongress 2012@ sState of the Art and Practice in Geotechnical Engineer*ing (pp. 2037-2047). ASCE.

El-Sekelly, W., Mercado, V., Abdoun, T., Zeghal, M. & El-Ganainy, H. (2013). Bender elements and system identification for estimation of Vs. International *Journal of Physical Modelling in Geotechnics,* 13(4): 111-121. DOI 10.1680/ijpmg.13.00004.

El-Sekelly, W., Tessari, A. & Abdoun, T. (2014). Shear wave velocity measurement in the centrifuge using bender elements. *Geotechnical Testing Journal,* 37(4): 689-704.

Eseller-Bayat, E., Gokyer, S., Yegian, M. K., Deniz, R. O. & Alshawabkeh, A. (2013). Bender Elements and Bending Disks for Measurement of Shear and Compression Wave Velocities in Large Fully and Partially Saturated Sand Specimens. *Geotechnical testing journal,* 36(2): 275-282.

Everett, M. E. (2013). *Near-surface applied geophysics*. UK. Cambridge University Press.

Fabien-Ouellet, G. & Fortier, R. (2014). Using all seismic arrivals in shallow seismic investigations. *Journal of Applied Geophysics,* 103, 31-42.

Farooq, K., Rogers, J. D. & Ahmed, M. F. (2015). Effect of Densification on the Shear Strength of Landslide Material: A Case Study from Salt Range, Pakistan. *Earth Science Research,* 4(1): 113. DOI: 10.5539/esr.v4n1p113.

Ferreira, C. (2008). *The use of seismic wave velocities in the measurement of stiffness of a residual soil*. University of Porto. Ph.D. Thesis.

Ferreira, C., Martins, J. P. & Correia, A. G. (2014). Determination of the small-strain stiffness of hard soils by means of bender elements and accelerometers. *Geotechnical and Geological Engineering,* 32(6): 1369-1375. DOI 10.1007/s10706-013-9678-7.

Ferreira, C., Viana da Fonseca, A. & Santos, J. A. (2007). Comparison of Simultaneous Bender Elements and Resonant-Column Tests on Porto Residual Soil and Toyoura Sand. In *Geomechanics: Laboratory Testing, Modeling and Applications*–A Collection of Papers of the Geotechnical Symposium in Rome (pp. 16-17).

Fonseca, A. V., Ferreira, C. & Fahey, M. (2009). A Framework Interpreting Bender Element Tests, Combining Time-Domain and Frequency-Domain Methods. *Geotechnical Testing Journal,* 32(2): 91-107.

Foti, S. (2013). Combined Use of Geophysical Methods in Site Characterization. In Coutinho, R. Q. & Mayne, P. W. (Eds.). *Geotechnical and Geophysical Site Characterization 4*. London & New York. CRC Press. pp: 43-61.

Foti, S., Lai, C. G., Rix, G. J. & Strobbia, C. (2014). *Surface wave methods for near-surface site characterization*. London & New York. CRC Press.

Francisca, F., Yun, T. S., Ruppel, C. & Santamarina, J. C. (2005). Geophysical and geotechnical properties of near-seafloor sediments in the northern Gulf of Mexico gas hydrate province. *Earth and Planetary Science Letters*, 237(3): 924-939.doi:10.1016/j.epsl.2005.06.050.

Fu, L., Zeng, X. & Figueroa, J. L. (2004). Shear Wave Velocity Measurement in Centrifuge Using Bender Elements. *International Journal of Physical Modelling in Geotechnics,* 4(2): 1-11.

Gadallah, M. R. & Fisher, R. (2009). *Exploration geophysics*. Berlin Heidelberg. Springer Science & Business Media.

Gadallah, M. R. & Fisher, R. L. (2005). *Applied seismology: A comprehensive guide to seismic theory and application.* USA. PennWell Books.

Gajo, A., Fedel, A. & Mongiovi, L. (1997). Experimental Analysis of the Effects of Fluid-Solid Coupling on the Velocity of Elastic Waves in Saturated Porous Media. *Géotechnique,* 47(5): 993-1008.

Garg, A. & Ng, C. W. W. (2015). Investigation of soil density effect on suction induced due to root water uptake by Schefflera heptaphylla. *Journal of Plant Nutrition and Soil Science*, 178(4): 586-591. DOI: 10.1002/jpln.201400265.

Garga, V. K. & Madureira, C. J. (1985). Compaction Characteristics of River Terrace Gravel. *Journal of Geotechnical Engineering*, 111(8): 987-1007.

Germaine, J. T. & Germaine, A. V. (2009). *Geotechnical Laboratory Measurements for Engineers*. New Jersey, USA. John Wiley and Sons.

Germano, C. (2003). Flexure Mode Piezoelectric Transducers. *Audio and Electroacoustics, IEEE Transactions on*. 19(1): 6.

Geotechnical Digital Systems [GDS] Ltd. (2014). Hampshire, RG27 9GR, UK. GDS Bender Element System (GDSBES) Specification Trade Brochure.

Gratchev, I. B. & Sassa, K. (2015). Shear Strength of Clay at Different Shear Rates. *Journal of Geotechnical and Geoenvironmental Engineering*, 141(5): 06015002. DOI: 10.1061/(ASCE)GT.1943-5606.0001297.

Grit, M. & Kanli, A. I. (2016). Integrated Seismic Survey for Detecting Landslide Effects on High Speed Rail Line at Istanbul–Turkey. *Open Geosciences,* 8(1): 161-173.

Gu, X., Yang, J., Huang, M. & Gao, G. (2015). Bender element tests in dry and saturated sand: Signal interpretation and result comparison. *Soils and Foundations,* 55(5): 951-962. DOI: 10.1016/j.sandf.2015.09.002.

Guérif, J. (1990). Factors Influencing Compaction-Induced Increases in Soil Strength. *Soil and Tillage Research*, 16(1): 167-178.

Güllü, H. (2015). Unconfined compressive strength and freeze–thaw resistance of fine-grained soil stabilised with bottom ash, lime and superplasticiser. *Road Materials and Pavement Design,* 16(3): 608-634. DOI: 10.1080/14680629.2015.1021369.

Hamidi, A., Alizadeh, M. & Soleimani, S. M. (2009). Effect of particle crushing on shear strength and dilation characteristics of sand-gravel mixtures. *International Journal of Civil Engineering,* 7(1): 61-71.

Hamilton, E. L. (1976). Shear-Wave Velocity versus Depth in Marine Sediments: A Review. *Geophysics,* 41(5): 985-996.

Hanzawa, H., Nutt, N., Lunne, T., Tang, Y. X., & Long, M. (2007). A comparative study between the NGI direct simple shear apparatus and the Mikasa direct shear apparatus. *Soils and foundations,* 47(1), 47-58.

Hardy, S., Zdravkovic, L. & Potts, D. M. (2002). Numerical Interpretation of Continuously Cycled Bender Element Tests. NUMOG. *Sweets and Zeitlinger,* 595-600.

Hausmann, J., Steinel, H., Kreck, M., Werban, U., Vienken, T. & Dietrich, P. (2013). Two-dimensional geomorphological characterization of a filled abandoned meander using geophysical methods and soil sampling. *Geomorphology*, 201, 335-343.

Heitor, A., Indraratna, B. & Rujikiatkamjorn, C. (2013). Laboratory study of small-strain behavior of a compacted silty sand. *Canadian Geotechnical Journal*, 50(2): 179-188. doi:10.1139/cgj-2012-0037.

Hlasko, H. A. & Zeng, X. (2010). Piezoelectric probe for measurement of soil stiffness. *International Journal of Pavement Engineering*, 11(1): 25-35. DOI: 10.1080/10298430802465624.

Hoar, R. J. & Stokoe, K. H. (1978). Generation and Measurement of Shear Waves In-Situ. *Dynamic Geotechnical Testing*, 654, 3.

Horn, R., Taubner, H., Wuttke, M. & Baumgartl, T. (1994). Soil physical properties related to soil structure. *Soil and Tillage Research*, 30(2): 187-216.

Huang, Y. T., Huang, A. B., Kuo, Y. C. & Tsai, M. D. (2004). A Laboratory Study on the Undrained Strength of a Silty Sand from Central Western Taiwan. *Soil Dynamics and Earthquake Engineering*, 24(9): 733-743. doi:10.1016/j.soildyn.2004.06.013.

Hunt, R. E. (2005). *Geotechnical engineering investigation handbook*. 2nd ed. London & New York. CRC Press.

Hunt, R. E. (2007). *Geologic hazards: a field guide for geotechnical engineers*. London & New York. CRC Press.

Indian Roads Congress (IRC) (2014). *Guidelines on compaction equipment for road works Indian*. New Delhi, India.

Indraratna, B., Heitor, A. & Rujikiatkamjorn, C. (2012). Effect of compaction energy on shear wave velocity of dynamically compacted silty sand soil. In A. Jotisankasa, A. Sawangsuriya, S. Soralump & W. Mairaing (Eds.), *5th Asia-Pacific Conference on Unsaturated Soils*. Thailand. Kasetsart University. pp. 635-640.

Ismail, M. A., Sharma, S. S. & Fahey, M. (2005). A Small True Triaxial Apparatus with Wave Velocity Measurement. *Geotechnical Testing Journal*, 28(2): 1-10.

Jaime, A. & Romo, M. P. (1988). The Mexico Earthquake of September 19, 1985-Correlations Between Dynamic and Static Properties of Mexico City Clay. *Earthquake spectra*, 4(4): 787-804.

Jamiolkowski, M. (2012). Role of geophysical testing in geotechnical site characterization. *Soils and Rocks International Journal of Geotechnical and Geoenvironmental Engineering*, 2(2).

Jang, I. S., Kwon, O. S. & Chung, C. K. (2010). A pilot study of in-hole type CPTu using piezoelectric bender elements. In *2nd International Symposium on Cone Penetration Testing*. Huntington Beach, California.

Jewell, R. A., & Wroth, C. P. (1987). Direct shear tests on reinforced sand. *Geotechnique*, 37(1), 53-68.

Jovicic, V., Coop. M. R. & Simic, M. (1996). Objective Criteria for Determining G_{max} from Bender Element Tests, Technical Note. *Geotechnique*, 46(2): 357-362.

Jung, J.W., Park, C.S. & Mok, Y.J., 2008. Development of Buried Sensors for Stiffness Measurements of Soft Clays Using Bender Elements. In *Geotechnical Earthquake Engineering and Soil Dynamics IV* (pp. 1-10). ASCE. DOI: 10.1061/40975(318)42.

Jung, Y. H., Finno, R. J. & Cho, W. (2012). Stress–strain responses of reconstituted and natural compressible Chicago glacial clay. *Engineering Geology*, 129, 9-19. doi:10.1016/j.enggeo.2012.01.003.

Jung, Y. H., Kim, T. & Cho, W. (2014). G_{max} of Reclaimed Ground on the Western Coast of Korea Using Various Field and Laboratory Measurements. *Marine Georesources & Geotechnology*, 32(4): 351-367.

Kang, M. & Lee, J. S. (2015). Evaluation of the freezing–thawing effect in sand–silt mixtures using elastic waves and electrical resistivity. *Cold Regions Science and Technology*, 113, 1-11. doi:10.1016/j.coldregions.2015.02.004.

Kang, X. (2015). *Mechanical characteristics of organically modified fly ash-kaolinite mixtures*. Missouri University of Science and Technology. Ph.D. thesis.

Kang, X., Kang, G. & Bate, B. (2014). Measurement of Stiffness Anisotropy in Kaolinite Using Bender Element Tests in A Floating Wall Consolidometer. *Geotechnical* Testing *Journal*, 37(5): 1-15. doi:10.1520/GTJ20120205.

Karl, L. (2005). *Dynamic Soil Properties out of SCPT and Bender Element Tests with Emphasis on Material Damping*. Ghent University. Ph.D. thesis.

Karl, L. Haegemana, W. & Degrande, G. (2006). Determination Of The Material Damping Ratio And The Shear Wave Velocity With The Seismic Cone Penetration Test. *Soil Dynamics and Earthquake Engineering 26 (2006)* 1111–1126.

Karray, M., Ben Romdhan, M., Hussien, M. N. & Éthier, Y. (2015). Measuring shear wave velocity of granular material using the piezoelectric ring-actuator technique (P-RAT). *Canadian Geotechnical Journal*, 52(9): 1302-1317. doi: 10.1139/cgj-2014-0306.

Kearey, P. Brooksm M. Hill, I. (2002). *An Introduction to Geophysical Exploration*. 3rd ed. USA. Blackwell Science Ltd Editorial Offices.

Khandelwal, M. (2013). Correlating P-wave velocity with the physico-mechanical properties of different rocks. *Pure and Applied Geophysics*, 170(4): 507-514. doi:10.1007/s00024-012-0556-7.

Kim, D. S. & Park, H. C. (1999). Evaluation of ground densification using spectral analysis of surface waves (SASW) and resonant column (RC) tests. *Canadian Geotechnical Journal*, 36(2): 291-299.

Kim, D. S., Shin, M. K. & Park, H. C. (2001). Evaluation of density in layer compaction using SASW method. *Soil Dynamics and Earthquake Engineering*, 21(1): 39-46.

Kim, H. S., Jung, J. W., Lee, T. H. & Mok, Y. J. (2009). Estimating Field Properties of Soft Soil Using Penetration-Type S-Wave Probe. In *Recent Advancement in Soil Behavior, in Situ Test Methods, Pile Foundations, and Tunneling@ sSelected Papers from the 2009 GeoHunan International Conference* (pp. 83-88). ASCE.

Kirsch, R. (2009). *Groundwater Geophysics a Tool for Hydrogeology*. 2nd ed. Berlin Heidelberg. Springer.

Knappett, J. & Craig, R. F. (2012). *Craig's Soil Mechanics*. 8th ed. London & New York. Spon Press.

Knox, D.P.; Stokoe, K.H. & Kopperman, S.E. (1982). Effect of State of Stress on Velocity of Low Amplitude Shear Wave Propagating Along Principal Stress Directions in Dry Sand. *Geotechnical Engineering Research Report GR 82-23*. University of Texas at Austin.

Kokusho, T. & Yoshida, Y. (1997). SPT N-value and S-wave velocity for gravelly soil with different grain size distribution. *Soils and Foundations*, 37(4): 105-113

Kulkarni, M. P., Patel, A. & Singh, D. N. (2010). Application of shear wave velocity for characterizing clays from coastal regions. KSCE Journal of Civil Engineering, 14(3): 307-321. doi:10.1007/s12205-010-0307-1.

Lawrence, Jr. F.V. (1965). *Ultrasonic shear wave velocities in sand and clay. Massachusetts Institute of Technology*, Cambridge, Mass. Research Report R65–05.

Lee, C. J., Wang, C. R., Wei, Y. C. & Hung, W. Y. (2012). Evolution of the shear wave velocity during shaking modeled in centrifuge shaking table tests. *Bulletin of Earthquake Engineering*, 10(2): 401-420. DOI 10.1007/s10518-011-9314-y.

Lee, I. M., Kim, J. S., Yoon, H. K. & Lee, J. S. (2014). Evaluation of Compressive Strength and Stiffness of Grouted Soils using Elastic Waves. *Hindawi Publishing Corporation Scientific World Journal*, 2014, 215804.

Lee, J. & Santamarina, J. C. (2005). Bender Elements: Performance and Signal Interpretation. *Journal of Geotechnical and Geoenvironmental Engineering*, 131(9): 1063-1070. ©ASCE, ISSN 1090 0241/2005/9-1063–1070.

Lee, J. S. (2003). *High-resolution geophysical techniques for small-scale soil model testing*. Georgia Institute of Technology. PhD thesis.

Lee, J. S., Fernandez, A. L. & Santamarina, J. C. (2005). S-Wave Velocity Tomography: Small-Scale Laboratory Application. *Geotechnical Testing Journal*, 2 (4): 1-9.

Lee, J. S., Lee, J. Y., Kim, Y. M. & Lee, C. (2013). Stress-dependent and strength properties of gas hydrate-bearing marine sediments from the Ulleung Basin, East Sea, Korea. *Marine and Petroleum Geology*, 47, 66-76. doi:10.1016/j.marpetgeo.2013.04.006

Leong, E. C. & Cheng, Z. Y. (2016). Effects of Confining Pressure and Degree of Saturation on Wave Velocities of Soils. *International Journal of Geomechanics*, D4016013.DOI: 10.1061/(ASCE)GM.1943-5622.0000727.

Leong, E. C., Yeo, S. H. & Rahardjo, H. (2004). Measurement of Wave Velocities and Attenuation Using an Ultrasonic Test System. *Canadian geotechnical journal*, 41(5): 844-860.

Leong, E.C., Cahyadi, J. & Rahardjo, H. (2009). Measuring Shear and Compression Wave Velocities of Soil Using Bender-Extender Elements. *Canadian geotechnical journal*, 46: 792-812.

Leong, E.C., Yeo, S.H. & Rahardjo, H. (2005). Measuring Shear Wave Velocity Using Bender Elements. *Geotechnical Testing Journal*, 28(5): 488-498.

Li, Q., Ng, C. W. W. & Liu, G. B. (2012). Determination of small-strain stiffness of Shanghai clay on prismatic soil specimen. *Canadian geotechnical journal*, 49(8): 986-993. doi:10.1139/T2012-050.

Li, Y. (2013). Effects of particle shape and size distribution on the shear strength behavior of composite soils. *Bulletin of Engineering Geology and the Environment*, 72(3-4): 371-381. DOI: 10.1007/s10064-013-0482-7.

Li, Y., Chan, L. S., Yeung, A. T. & Xiang, X. (2013a). Effects of test conditions on shear behaviour of composite soil. *Proceedings of the ICE-Geotechnical Engineering*, 166(3): 310-320. DOI: 10.1680/geng.11.00013.

Li, Y., Huang, R., Chan, L. S. & Chen, J. (2013b). Effects of particle shape on shear strength of clay-gravel mixture. *KSCE Journal of Civil Engineering*, 17(4): 712-717.

Lillie, R. J. (1999). *Whole Earth Geophysics an Introductory Textbook for Geologists and Geophysicists*. USA. Prentice Hall Upper Saddle River.

Lings, M. L. & Greening, P. D. (2001). A Novel Bender/Extender Element for Soil Testing, Technical Note. *Geotechnique*, 51, No. 8, 713-717.

Liu, H. L., Deng, A. & Chu, J. (2006b). Effect of different mixing ratios of polystyrene pre-puff beads and cement on the mechanical behaviour of lightweight fill. *Geotextiles and Geomembranes*, 24(6): 331-338. doi:10.1016/j.geotexmem.2006.05.002.

Liu, X. L., Loo, H., Min, H., Deng, J. H., Tham, L. G. & Lee, C. F. (2006a). Shear strength of slip soils containing coarse particles of Xietan landslide. *Geotechnical Special Publication*, (151): 142-149. DOI: 10.1061/40863(195)13.

Long, M. & Donohue, S. (2010). Characterization of Norwegian Marine Clays with Combined Shear Wave Velocity and Piezocone Cone Penetration Test (CPTU) Data. *Canadian geotechnical journal*, 47: 709–718.

Lopes, I., Santos, J. A. & Gomes, R. C. (2014). V S profile: measured versus empirical correlations—a Lower Tagus river valley example. *Bulletin of Engineering Geology and the Environment*, 73(4): 1127-1139.

Lowrie, W. (2007). *Fundamentals of geophysics*. 2nd ed. UK. Cambridge university press.

Lutgens, F. K. & Tarbuck, E. J. (2012). *Essentials of geology*. 11th ed. USA. Pearson Education, Inc.

Madun, A (2012). *Seismic Evaluation of Vibrostone Column*. The University of Birmingham. Ph.D. thesis.

Maheswari, R. U., Boominathan, A. & Dodagoudar, G. R. (2010). Use of surface waves in statistical correlations of shear wave velocity and penetration resistance of Chennai soils. *Geotechnical and Geological Engineering*, 28(2): 119-137.

Mandal, T., Tinjum, J. M. & Edil, T. B. (2016). Non-destructive testing of cementitiously stabilized materials using ultrasonic pulse velocity test. *Transportation Geotechnics*, 6, 97–107. doi:10.1016/j.trgeo.2015.09.003.

Martínez, J., Rey, J., Gutiérrez, L. M., Novo, A., Ortiz, A. J., Alejo, M. & Galdón, J. M. (2015). Electrical resistivity imaging (ERI) and ground-penetrating radar

(GPR) survey at the Giribaile site (upper Guadalquivir valley; southern Spain). *Journal of Applied Geophysics*, 123, 218-226.

Martínez-Moreno, F. J., Galindo-Zaldívar, J., Pedrera, A., Teixido, T., Ruano, P., Peña, J. A., Ruiz-Constán, A., González-Castillo, L., López-Chicano, L. & Martín-Rosales, W. (2014). Integrated geophysical methods for studying the karst system of Gruta de las Maravillas (Aracena, Southwest Spain). *Journal of Applied Geophysics*, 107, 149-162.

Martinho, E. & Dionísio, A. (2014). Main geophysical techniques used for non-destructive evaluation in cultural built heritage: a review. *Journal of Geophysics and Engineering*, 11(5): 053001.

Matasovica, N. Kavazanjian Jr, E. Anirban De. Dunnd, J. (2006). CPT-Based Seismic Stability Assessment of a Hazardous Waste Site. *Soil Dynamics and Earthquake Engineering*, 26:201–208.

Matsushi, Y. & Matsukura, Y. (2006). Cohesion of unsaturated residual soils as a function of volumetric water content. *Bulletin of Engineering Geology and the Environment*, 65(4): 449-455. DOI: 10.1007/s10064-005-0035-9.

Mavko, G. Mukerj, T. Dvorkin, J. (2009). *The Rock Physics Handbook, Tools for Seismic Analysis of Porous Media*. 2nd ed. UK. Cambridge University Press.

Mayne, P. W., Christopher, B. R. & DeJong, J. (2002). *Manual on Subsurface Investigations*. Nat. Highway Inst. Sp. Pub. FHWA NHI-01–031. Fed. Highway Administ, Washington, DC.

McDowell, P. W., Barker, R. D., Butcher, A. P., Culshaw, M., Jackosn, P. D., McCann, D. M., Skipp, B. O., Matthews, S. L. & Arthur, J. C. R. (2002). *Geophysics in engineering investigations*. Construction Industry Research and Information Association © ClRlA.

Megson, T. H. G. (2014). *Structural and stress analysis*. 3rd ed. USA. Butterworth-Heinemann.

Mendoza, C. & Colmenares, J. (2006) Influence of the Suction on the Stiffness at Very Small Strains. *Unsaturated Soils*, 2006: 529-540. doi: 10.1061/40802(189)40.

Miao, H., Wang, G., Yin, K., Kamai, T. & Li, Y. (2014). Mechanism of the slow-moving landslides in Jurassic red-strata in the Three Gorges Reservoir, China. *Engineering Geology*, 171, 59-69. DOI: 10.1016/j.enggeo.2013.12.017.

Miao, L. Chen, G. & Hong, Z. (2006). Application of Dynamic Compaction in Highway: A Case Study. *Geotechnical and Geological Engineering,* (2006) 24: 91–99.

Miller, S. & Stewart, R. (1991). The Relationship between Elastic-Wave Velocities and Density in Sedimentary Rocks: A proposal. CREWES Research report, 206-273

Milsom, J. & Eriksen, A. (2011). *Field geophysics*. 4th ed. UK. John Wiley & Sons.

Mitchell, J. K. & Soga, K. (2005). *Fundamentals of Soil Behavior*. 3rd ed. Canada. Wiley.

Mohamad, E. T., Alshameri, B. A., Kassim, K. A. & Gofar, N. (2011). Shear strength behaviour for older alluvium under different moisture content. *Electronic Journal of Geotechnical Engineering,* 16(F). 605-617.

Mohamed, A. M., El Ata, A. A., Azim, F. A. & Taha, M. A. (2013). Site-specific shear wave velocity investigation for geotechnical engineering applications using seismic refraction and 2D multi-channel analysis of surface waves. NRIAG *Journal of Astronomy and Geophysics,* 2(1): 88-101.

Mohsin, A. K. M. & Airey, D. W. (2005). Influence of Cementation and Density on G_{max} for Sand. In *16th International Conference on Soil Mechanics and Geotechnical Engineering*. Osaka, Japan. pp. 413-416.

Mok, Y. J., Park, C. S. & Nam, B. H. (2016). A borehole seismic source and its application to measure in-situ seismic wave velocities of geo-materials. *Soil Dynamics and Earthquake Engineering,* 80, 127-137.

Moldovan, I. D., Correia, A. G. & Pereira, C. (2016). Bender-based G_0 measurements: A coupled numerical–experimental approach. *Computers and Geotechnics,* 73, 24-36. DOI 10.1016/j.compgeo.2015.11.011.

Mouazen, A. M., Ramon, H. & De Baerdemaeker, J. (2002). SW—Soil and Water: Effects of Bulk Density and Moisture Content on Selected Mechanical Properties of Sandy Loam Soil. *Biosystems Engineering,* 83(2): 217-224. DOI: 10.1016/S1537-5110(02)00149-6.

Murillo, C. A., Thorel, L. & Caicedo, B. (2009). Spectral analysis of surface waves method to assess shear wave velocity within centrifuge models. *Journal of Applied Geophysics,* 68(2): 135-145. doi:10.1016/j.jappgeo.2008.10.007.

Murillo, C., Sharifipour, M., Caicedo, B., Thorel, L. & Dano, C., 2011. Elastic parameters of intermediate soils based on bender-extender elements pulse tests. *Soils and foundations,* 51(4): pp.637-649. DOI: 10.3208/sandf.51.637.

Mutman, U. & Kavak, A. (2013). An in situ low-pressure grouting application. *Proceedings of the Institution of Civil Engineers-Geotechnical Engineering,* 166(4): 375-388.

Naeini, S. A. & Baziar, M. H. (2004). Effect of fines content on steady-state strength of mixed and layered samples of a sand. *Soil Dynamics and Earthquake Engineering,* 24(3): 181-187. DOI: 10.1016/j.soildyn.2003.11.003.

Naeini, S. A. (2006). The ultimate shear behavior of loose gravelly sandy soils. *The Geological Society of London. IAEG2006*: 526.

Ni, S. H., Yang, Y. Z. & Huang, Y. H. (2014). An EMD-based procedure to evaluate the experimental dispersion curve of the SASW method. *Journal of the Chinese Institute of Engineers,* 37(7): 883-891.

Nicholson, P. G. (2015). *Soil improvement and ground modification methods*. Amsterdam. Butterworth-Heinemann.

Ning, Z. & Evans, T. M. (2013). Discrete Element Method Study of Shear Wave Propagation in Granular Soil. In *Proceeding of the 18th ICSMGE*. Paris. pp. 1031-1034.

Ning, Z., Khoubani, A. & Evans, T. M. (2015). Shear wave propagation in granular assemblies. *Computers and Geotechnics,* 69, 615-626.

Nunziata, C., De Nisco, G. & & Panza, G. F. (2009). S-waves profiles from noise cross correlation at small scale. *Engineering Geology,* 105(3): 161-170.

Ogino, T., Kawaguchi, T., Yamashita, S. & Kawajiri, S. (2015). Measurement deviations for shear wave velocity of bender element test using time domain, cross-correlation, and frequency domain approaches. *Soils and Foundations,* 55(2): 329-342. DOI: 10.1016/j.sandf.2015.02.009.

Okada, Y., Sassa, K. & Fukuoka, H. (2004). Excess pore pressure and grain crushing of sands by means of undrained and naturally drained ring-shear tests. *Engineering geology,* 75(3): 325-343. DOI:10.1016/j.enggeo.2004.07.001.

Okonta, F. (2015). Preliminary laboratory assessments of a lightweight geocomposite material for embankment fill application. S*outh African Journal of Science,* 111(3-4): 1-9. DOI: 10.17159/sajs.2015/20130262.

Omar, T. & Sadrekarimi, A. (2014). Specimen size effects on behavior of loose sand in triaxial compression tests. *Canadian Geotechnical Journal*, 52(6): pp732-746. DOI: 10.1139/cgj-2014-0234.

Omidvar, M., Iskander, M. & Bless, S. (2012). Stress-strain behavior of sand at high strain rates. *International journal of impact engineering*, 49, 192-213. DOI: 10.1016/j.ijimpeng.2012.03.004.

Ortiz, O. F. P. (2004). *Small and Large Strain Monitoring of Unsaturated Soil Behavior by Means of Multiaxial Testing And Shear Wave Propagation*. Louisiana State University. Ph.D. thesis.

Park, C. B., Miller, R. D. & Miura, H. (2002). *Optimum field parameters of an MASW survey*. Ext. Abstract, Society of Exploration Geophysicists of Japan, Tokyo, 22-23.

Parolai, S., Bindi, D., Ansal, A., Kurtulus, A., Strollo, A. & Zschau, J. (2010). Determination of Shallow S-Wave Attenuation by Down-Hole Waveform Deconvolution: A Case Study in Istanbul (Turkey). *Geophysical Journal International*, 181(2): 1147-1158.

Patel, A., Singh, D. N. & Singh, K. K. (2010). Performance Analysis of Piezo-Ceramic Elements in Soils. *Geotechnical and Geological Engineering*, 28(5): 681-694.

Pennington, D. S., Nash, D. F. & Lings, M. L. (2001). Horizontally Mounted Bender Elements for Measuring Anisotropic Shear Moduli in Triaxial Clay Specimens. *Geotechnical Testing Journal*, 24(2): 133-144.

Pennington, D. S., Nash, D. F. T. & Lings, M. L. (1997). Anisotropy of G_0 shear stiffness in Gault Clay. *Géotechnique*, 47(3): 391-398.

Perret, D., Locat, J. & Martignoni, P. (1996). Thixotropic behavior during shear of a fine-grained mud from Eastern Canada. *Engineering Geology*, 43(1): 31-44. DOI:10.1016/0013-7952(96)00031-2.

Piriyakul, K. (2013). Application of the Non-Destructive Testing Method to Determine the G_{max} of Bangkok Clay. *Applied Mechanics and Materials*,418: 157-160. doi:10.4028/www.scientific.net/AMM.418.157.

Pitman, T. D., Robertson, P.K. & Sego, D.C. (1994). Influence of fines on the collapse of loose sands. *Canadian Geotechnical Journal*, 31(5): 728-739. DOI: 10.1139/t94-084.

Prakasha, K. S. & Chandrasekaran, V. S. (2005). Behavior of marine sand-clay mixtures under static and cyclic triaxial shear. *Journal of geotechnical and* *geoenvironmental engineering*, 131(2): 213-222. DOI: 10.1061/(ASCE)1090-0241(2005)131:2(213).

Prasad, M., Zimmer, M. A., Berge, P. A. & Bonner, B. P. (2005). Laboratory Measurements of Velocity and Attenuation in Sediments. In: *Butler, D. K. (Ed.). Near-Surface Geophysics*. USA. Society of Exploration Geophysicists. pp. 491-502.

Rahman, M. M., Lo, S. R. & Cubrinovski, M. (2010). Equivalent granular void ratio and behaviour of loose sand with fines. International Conferences on Recent Advances in *Geotechnical Earthquake Engineering and Soil Dynamics*. San Diego, Clifornia, USA. (Paper 16): 1-9.

Rees, S., Le Compte, A. & Snelling, K. (2013). A New Tool for the Automated Travel Time Analyses of Bender Element Tests. *Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering.* Paris 2013. pp. 2843-2846.

Reynolds, J. M. (2011). *An introduction to applied and environmental geophysics*. 2nd ed. UK. John Wiley & Sons.

Rio, J.; Greening, P. & Medina, L. (2003). Influence of Sample Geometry on Shear Wave Propagation Using Bender Elements. *Proceedings of Deformation Characteristics of Geomaterials*, Lyon, France, 22-24 September, Lyon, France:Balkema, pp. 963-967.

Rio, M. E. (2006). *Advances in Laboratory Geophysics Using Bender Elements*. University of London. Ph.D. thesis.

Robertson, P. K., Sasitharan, S., Cunning, J. C. & Sego, D. C. (1995). Shear-wave velocity to evaluate in-situ state of Ottawa sand. *Journal of Geotechnical Engineering,* 121(3): 262-273. doi: 10.1061/(ASCE)0733-9410(1995)121:3(262).

Robinson, E. S. Coruh, C. (1988). *Basic Exploration Geophysics*. New York. John Wiley and Sons, Inc.

Roje-Bonacci, T., Miščević, P. & Salvezani, D. (2014). Non-destructive monitoring methods as indicators of damage cause on Cathedral of St. Lawrence in Trogir, Croatia. *Journal of Cultural Heritage*, 15(4): 424-431.

Russell, E. R. & Renk, M. (1999). *Soils Sampling and Testing Training Guide for Field and Laboratory Technicians on Roadway Construction* (No. K-TRAN: KSU-96-10).

Sa´nchez-Salinero, I., Roesset, J. M. & Stokoe, K. H. (1986). *Analytical Studies of Body Wave Propagation and Attenuation*. Geotechnical Engineering Report No GR86-15. Civil Engineering Department, University of Texas at Austin. 272 pages.

Sadek, M.A., Chen, Y. & Liu, J. (2011). Simulating shear behavior of a sandy soil under different soil conditions. *Journal of Terramechanics*, 48(6): 451-458. DOI: 10.1016/j.jterra.2011.09.006.

Santagata, M. & Kang, Y. I. (2007). Effects of geologic time on the initial stiffness of clays. *Engineering geology*, 89(1): 98-111. doi:10.1016/j.enggeo.2006.09.018.

Santamarina, J. C. Klein, K. A & Fam, M. A. (2001). *Soils and Waves, Particulate Material Behaviour Characterization and Process Monitoring*. John Wiley and Sons Ltd.

Santamarina, J. C., Rinaldi, V. A., Fratta, D., Klein, K. A., Wang, Y. H., Cho, G. C. & Cascante, G. (2005). A Survey of Elastic and Electromagnetic Properties of Near-Surface Soils. In: Butler, D. K. (Ed.). *Near-Surface Geophysics*. Society of Exploration Geophysicists. pp. 71-87.

Sas, W., Gabryś, K., Soból, E. & Szymański, A. (2016). Dynamic Characterization of Cohesive Material Based on Wave Velocity Measurements. *Applied Sciences,* 6(2), 49. Doi:10.3390/app6020049.

Sawangsuriya, A., Fall, M. & Fratta, D. (2008). Wave-based techniques for evaluating elastic modulus and Poisson's ratio of laboratory compacted lateritic soils. *Geotechnical and Geological Engineering,* 26(5): 567-578. DOI 10.1007/s10706-008-9190-7.

Schnaid, F. (2009). *In situ testing in geomechanics: the main tests*. New York. Taylor & Francis.

Schneider, J. A., Mayne, P. W. & Rix, G. J. (2001). Geotechnical Site Characterization in the Greater Memphis Area Using Cone Penetration Tests. *Engineering Geology*, 62(1): 169-184.

Shahnazari, H., Heshmati, A.A. & Sarbaz, H. (2015). Effect of cyclic pre-straining on the dynamic behavior of very dense sand. *KSCE Journal of Civil Engineering*, 19(1): 63-73. DOI: 10.1007/s12205-014-0471-9.

Shearer, P. M. (2009). *Introduction to Seismology*. 2nd ed. UK. Cambridge University Press.

Shi-ming, W. & Long-zhu, C. (1989). Propagation Velocities of Elastic Waves In Saturated Soils. *Applied Mathematics and Mechanics,* 10(7): 631-638.

Shin, H. & Santamarina, J. C. (2012). Role of particle angularity on the mechanical behavior of granular mixtures. *Journal of Geotechnical and Geoenvironmental Engineering,* 139(2): 353-355. DOI: 10.1061/(ASCE)GT.1943-5606.0000768.

Shokri, B. J., Ardejani, F. D. & Moradzadeh, A. (2016). Mapping the flow pathways and contaminants transportation around a coal washing plant using the VLF-EM, Geo-electrical and IP techniques—A case study, NE Iran. *Environmental Earth Sciences,* 75(1): 1-13.

Sil, A. & Sitharam, T. G. (2014). Dynamic site characterization and correlation of shear wave velocity with standard penetration test 'N'values for the city of Agartala, Tripura state, India. *Pure and Applied Geophysics,* 171(8): 1859-1876.

Simm, R., Bacon, M. & Bacon, M. (2014). *Seismic Amplitude: An interpreter's handbook*. UK. Cambridge University Press.

Simoni, A. & Houlsby, G. T. 2006. The direct shear strength and dilatancy of sand–gravel mixtures. *Geotechnical and Geological Engineering*, 24(3): 523-549. DOI: 10.1007/s10706-004-5832-6.

Simpson, D. C. & Evans, T. M. (2015). Behavioral Thresholds in Mixtures of Sand and Kaolinite Clay. *Journal of Geotechnical and Geoenvironmental Engineering*, 04015073. DOI: 10.1061/(ASCE)GT.1943-5606.0001391.

Sirles, P. C. (2006). *Use of geophysics for transportation projects, A Synthesis of Highway Practice*. Transportation Research Board, Washington, D.C.

Stark, T. D. & Eid, H. T. (1994). Drained residual strength of cohesive soils. *Journal of Geotechnical Engineering*, 120(5): 856-871. DOI: 10.1061/(ASCE)0733-9410(1994)120:5(856).

Stokoe, K.H. & Santamarina, J.C. (2000). Seismic-Wave based Testing in Geotechnical Engineering. *GeoEng 2000, Melbourne*, CD-Rom.

Stone, K. J., & Wood, D. M. (1992). Effects of dilatancy and particle size observed in model tests on sand. *Soils and Foundations,* 32(4): 43-57.

Suzuki, M., Kobayashi, K., Yamamoto, T., Matsubara, T. & Hukuda, J. (2004). Influence of shear rate on residual strength of clay in ring shear test. *Research Report,* 55, 49-62.

Tabibnejad, A., Heshmati, A., Salehzadeh, H. & Tabatabaei, S.H. (2015). Effect of gradation curve and dry density on collapse deformation behavior of a rockfill material. *KSCE Journal of Civil Engineering*, 19(3): 631-640. doi:10.1007/s12205-013-0682-5.

Tang, C., Pei, X., Wang, D., Shi, B. & Li, J. (2014). Tensile Strength of Compacted Clayey Soil. *Journal of Geotechnical and Geoenvironmental Engineering*, 141(4): 04014122. DOI: 10.1061/(ASCE)GT.1943-5606.0001267.

Tang, X. W., Ma, L. & Shao, Q. (2013). Experimental Investigation on Effect of Bentonite Content to the Liquefaction Potential in Saturated Sand. *Electronic Journal of Geotechnical Engineering*, 18(G):1409-1417.

Telford, W. M., Geldart, L. P. & Sheriff, R. E. (1990). *Applied geophysics*. 2nd ed. UK. Cambridge university press.

Tezcan, S. S., Ozdemir, Z. & Keceli, A. (2009). Seismic technique to determine the allowable bearing pressure for shallow foundations in soils and rocks. *Acta Geophysica*, 57(2): 400-412.

Thakur, N. K. & Rajput, S. (2010). *Exploration of gas hydrates: Geophysical techniques*. London New York. Springer Science & Business Media.

Thevanayagam, S. (1998). Effect of fines and confining stress on undrained shear strength of silty sands. *Journal of Geotechnical and Geoenvironmental Engineering*, 124(6): 479-491. DOI: 10.1061/(ASCE)1090-0241(1998)124:6(479).

Thevanayagam, S., Fiorillo, M. & Liang, J. (2000). Effect of non-plastic fines on undrained cyclic strength of silty sands. *Geotechnical Special Publication*, 77-91. DOI: 10.1061/40520(295)6.

Thevanayagam, S., Ravishankar, K. & Mohan, S. (1997). Effects of fines on monotonic undrained shear strength of sandy soils. *Geotechnical testing journal*, 20(4): 394-406. DOI: 10.1520/GTJ10406J.

Tokeshi, K., Harutoonian, P., Leo, C. J. & Liyanapathirana, S. (2013). Use of surface waves for geotechnical engineering applications in Western Sydney. *Advances in Geosciences*, 35(35): 37-44.

Toufigh, V., Ouria, A., Desai, C. S., Javid, N., Toufigh, V. & Saadatmanesh, H. (2015). Interface Behavior Between Carbon-Fiber Polymer and Sand. *Journal of Testing and Evaluation*, 44(1): 385-390. DOI:10.1520/JTE20140153.

Ueda, T., Matsushima, T. & Yamada, Y. (2011). Effect of particle size ratio and volume fraction on shear strength of binary granular mixture. *Granular Matter*, 13(6): 731-742. DOI: 10.1007/s10035-011-0292-1.

Ulucan, Z. Ç., Türk, K. & Karataş, M. (2008). Effect of mineral admixtures on the correlation between ultrasonic velocity and compressive strength for self-compacting concrete. *Russian Journal of Nondestructive Testing,* 44(5): 367-374.

Valle-Molina, C. & Stokoe, K. H. (2012). Seismic measurements in sand specimens with varying degrees of saturation using piezoelectric transducers. *Canadian Geotechnical Journal,* 49(6): 671-685. doi:10.1139/T2012-033.

Verwaal, W. & Mulder, A. (2004). *Soil Mechanics Laboratory Manual. Compiled for the DGM Geotechncial Laboratory*. DGM-SDS project on slope stability and ITC, The Netherlands.

Viggiani, G. & Atkinson, J. H. (1995a). Interpretation of Bender Element Tests, Technical Note. *Geotechnique,* 45(1): 149-154.

Viggiani, G. & Atkinson, J. H. (1995b). Stiffness of Fine-Grained Soil at Very Small Strains. *Geotechnique,* 45(2): 249-265.

Viggiani, G. (1992). *Small strain stiffness of fine grained soils*. City University London, UK. PhD thesis.

Vithana, S. B., Nakamura, S., Gibo, S., Yoshinaga, A. & Kimura, S. (2012). Correlation of large displacement drained shear strength of landslide soils measured by direct shear and ring shear devices. *Landslides,* 9(3): 305-314. DOI: 10.1007/s10346-011-0301-9.

Wadhwa, S. Ghosh, N. & Subba Rao, C. (2010). Empirical Relation for Estimating Shear Wave Velocity from Compressional Wave Velocity of Rocks. *J. Ind. Geophys,* 14(1): 21-30.

Wang, G., Suemine, A. & Schulz, W. H. (2010). Shear-rate-dependent strength control on the dynamics of rainfall-triggered landslides, Tokushima Prefecture, Japan. *Earth Surface Processes and Landforms,* 35(4): 407-416. DOI: 10.1002/esp.1937.

Wang, J. J., Zhang, H. P., Tang, S. C. & Liang, Y. (2013b). Effects of particle size distribution on shear strength of accumulation soil. *Journal of Geotechnical and Geoenvironmental Engineering,* 139(11): 1994-1997. DOI: 10.1061/(ASCE)GT.1943-5606.0000931.

Wang, J.J., Zhang, H.P., Wen, H.B. & Liang, Y. (2015). Shear strength of an accumulation soil from direct shear test. *Marine Georesources & Geotechnology,* 33(2): 183-190. DOI: 10.1080/1064119X.2013.828821.

Wang, S.Y., Chan, D.H., Lam, K.C. & Au, S.K.A. (2013a). A new laboratory apparatus for studying dynamic compaction grouting into granular soils. *Soils and Foundations*, 53(3): 462-468. DOI:10.1016/j.sandf.2013.04.007.

Wang, Y. H., Lo, K. F., Yan, W. M. & Dong, X. B. (2007). Measurement Biases in The Bender Element Test. *Journal of Geotechnical and Geoenvironmental Engineering*, 133(5): 564-574.

Whalley, W. R., Jenkins, M. & Attenborough, K. (2012). The Velocity of Shear Waves in Unsaturated Soil. *Soil and Tillage Research*, 125, 30-37.

Whitlow, R. (2001). *Basic Soil Mechanics*. 4th ed. UK. Pearson Education Ltd.

Wichtmann, T., Hernández, M. N. & Triantafyllidis, T. (2015). On the influence of a non-cohesive fines content on small strain stiffness, modulus degradation and damping of quartz sand. *Soil Dynamics and Earthquake Engineering*, 69, 103-114. doi:10.1016/j.soildyn.2014.10.017.

Wightman, W. E., F. Jalinoos, P. Sirles & K. Hanna. (2003). *Application of Geophysical Methods to Highway Related Problems*. Publication No. FHWA-IF-04-021. Central Federal Lands Highway Division, FHWA, U.S. Department of Transportation.

Woods, R. D. (1994). Laboratory Measurement of Dynamic Soil Properties. *ASTM Special Technical Publication*, 1213, 165-165.

Wu, P. K., Matsushima, K. & Tatsuoka, F. (2008). Effects of specimen size and some other factors on the strength and deformation of granular soil in direct shear tests. *Geotechnical Testing Journal*, 31(1): 473.

Yagiz, S. (2001). Brief note on the influence of shape and percentage of gravel on the shear strength of sand and gravel mixtures. *Bulletin of Engineering Geology and the Environment*, 60(4): 321-323. DOI: 10.1007/s100640100122.

Yamashita, S., Kawaguchi, T., Nakata, Y., Mikami, T., Fujiwara, T. & Shibuya, S. (2009). Interpretation of international parallel test on the measurement of G_{max} using bender elements. *Soils and foundations*, 49(4): 631-650.

Yang, J. & Gu, X. Q. (2013). Shear Stiffness of Granular Material at Small Strains: Does It Depend on Grain Size?. *Géotechnique*, 63(2): 165-179. doi:10.1680/geot.11.P.083.

Yang, J. & Liu, X. (2016). Shear wave velocity and stiffness of sand: the role of non-plastic fines. *Géotechnique*, 66(6): 500-514. doi:10.1680/jgeot.15.P.205.

Yang, S. R. & Lin, H. D. (2009). Influence of soil suction on small-strain stiffness of compacted residual subgrade soil. *Transportation Research Record: Journal of the Transportation Research Board (2101):* 63-71. doi: 10.3141/2101-08.

Yasar, E. & Erdogan, Y. (2004). Correlating sound velocity with the density, compressive strength and Young's modulus of carbonate rocks. International *Journal of Rock Mechanics and Mining Sciences,* 41(5): 871-875. doi:10.1016/j.ijrmms.2004.01.012.

Yazdanjou, V., Salimi, N. & Hamidi, A. 2008. Effect of gravel content on the shear behavior of sandy soils. *In proceeding of 4th National Congress on Civil Engineering*. Tehran University, Iran. pp. 1-5.

Yesiller, N., Inci, G. & Miller, C. J. 2000. Ultrasonic testing for compacted clayey soils. *Geotechnical Special Publication,* 54-68. DOI: 10.1061/40510(287)5.

Yong-hong, Y., Jian-guo, Z., Jian-hui, Z., Shu-zhen, L., Cheng-hua, W. & Qing-hua, X. (2005). Impacts of soil moisture content and vegetation on shear strength of unsaturated soil. *Wuhan University Journal of Natural Sciences*, 10(4): 682-688. DOI: 10.1007/BF02830380.

Yoon, H. K. & Lee, J. S. (2010). Field velocity resistivity probe for estimating stiffness and void ratio. *Soil Dynamics and Earthquake Engineering*, 30(12): 1540-1549. doi:10.1016/j.soildyn.2010.07.008.

Yordkayhun, S., Sujitapan, C. & Chalermyanont, T. (2014). Joint analysis of shear wave velocity from SH-wave refraction and MASW techniques for SPT-N estimation. *Songklanakarin J. Sci. Technol.*, 36.

Youn, J. U., Choo, Y. W. & Kim, D. S. (2008). Measurement of small-strain shear modulus G max of dry and saturated sands by bender element, resonant column, and torsional shear tests. *Canadian Geotechnical Journal*, 45(10): 1426-1438. doi:10.1139/T08-069.

Yun, T. S., Narsilio, G. A. & Santamarina, J. C. (2006). Physical characterization of core samples recovered from Gulf of Mexico. *Marine and Petroleum Geology*, 23(9): 893-900. doi:10.1016/j.marpetgeo.2006.08.002.

Zekkos, D., Sahadewa, A., Woods, R. D. & Stokoe, K. H. (2013). Development of Model for Shear-Wave Velocity of Municipal Solid Waste. *Journal of Geotechnical and Geoenvironmental Engineering*, 140(3): 04013030.

Zeng, C. & Feng, W. (2014). Influence of Clay Content on Liquefaction and Post-Liquefaction of Silt. *Electronic Journal of Geotechnical Engineering*, 19(C): 721-731.

Zeng, X. & Ludwig, F. J. (2006). Measurement of base and subgrade layer stiffness using bender element technique. U.S. Patent No. 7,082,831.

Zeng, X. & Ni, B. (1999). Stress-Induced Anisotropic G_{max} of Sands and Its Measurement. *Journal of Geotechnical and Geoenvironmental Engineering,* 125(9): 741-749.

Zeng, X., Agui, J. H. & Nakagawa, M. (2007). Wave Velocities in Granular Materials under Microgravity. *Journal of Aerospace Engineering,* 20(2): 116-123. doi:10.1061/(ASCE)0893-1321(2007)20:2(116).

Zeng, X., Figueroa, J. L. & Fu, L. (2003). Measurement of base and subgrade layer stiffness using bender element technique. In *Recent Advances in Materials Characterization and Modeling of Pavement Systems.* ASCE. pp. 35-45.

Zhao, S., Zhou, X. & Liu, W. (2015). Discrete element simulations of direct shear tests with particle angularity effect. *Granular Matter,* 17(6): 793-806. DOI: 10.1007/s10035-015-0593-x.

Zhou, Y. G., Chen, Y. M., Asaka, Y. & Abe, T. (2008). Surface-mounted bender elements for measuring horizontal shear wave velocity of soils. *Journal of Zhejiang University SCIENCE A*, 9(11): 1490-1496.

Zhou, Y. G., Sun, Z. B. & Chen, Y. M. (2016). Curved Raypaths of Shear Waves and Measurement Accuracy of Bender Elements in Centrifuge Model Tests. *Journal of Geotechnical and Geoenvironmental Engineering,* 04016008.

Zlatović, S. (1995). On the influence of nonplastic fines on residual strength. In *First International Conference on Earthquake Geotechnical Engineering*. Hrvatska znanstvena bibliografija i MZOS-Svibor. pp239-244.